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Preparation and acylation of biphenols

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THE PREPARATION AND ACYLATION OF BIPHENOLS

by

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I. INTRODUCTION

The Fries rearrangement is the conversion of a phenolic ester, on treatment with aluminum chloride, to ortho- or para-hydroxyketones or a mixture of the two.

There has been a considerable amount of work done on the single Fries rearrangement of monoesters,[1] however, very little has been done on the double Fries rearrangement of diesters.

The diesters which undergo the double Fries rearrangement may be classified into two major groups: (I) diesters of phenols and dicarboxylic acids, and (II) diesters of biphenols and monocarboxylic acids.

I. Diesters of Phenols and Dicarboxylic Acids.

There are several reports of the Fries rearrangement of diesters of dicarboxylic acids to give the corresponding bis(hydroxyketones), [2-7] while anomalous results have been reported for the attempted rearrangements of several diesters. The di-p-tolyl esters of oxalic, malonic and phthalic acids[6] gave 2-hydroxy-5-methylbenzoic acid, 4-hydroxy-6-methylcoumarin and 1-hydroxy-4-methylanthraquinone, respectively, when submitted to the conditions of the Fries rearrangement. The attempted rearrangement of diphenyl phthalate[8] gave phenolphthalein and 1-hydroxyanthraquinone.

II. Diesters of Biphenols and Monocarboxylic Acids.

The diacetate[9,10] and dipropanoate[9] esters of 4,4′-biphenol, when subjected to the conditions of the Fries rearrangement, have been reported to give 3,3′-diacetyl-4,4′-dihydroxybiphenyl and 3,3′-dipropanoyl-4,4′-dihydroxybiphenyl, respectively, but the rearrangement was unsuccessful[10] for 4,4′-biphenyl dilaurate and bi-o-cresyl dilaurate.

The rearrangement of diesters of 4,4′-biphenol, from the diacetate to the didodecanoate and including the dibenzoate, has been reported.[11]

Roffler and Thomas[12] observed that diesters of 4,4′-dihydroxydiphenylmethane, diacetate through dinonanoate and again including the dibenzoate, gave the desired 3,3′-diacyl-4,4′-dihydroxydiphenylmethanes except for the dihexanoyl ester. In this latter case an oil was obtained from which no product could be isolated.

Recently Thomas[13] has studied the Fries rearrangement of di-p-tolyl esters of dicarboxylic acids which contained linkages between the two ester groups other than a straight carbon chain. Di-p-tolyl esters of acids such as 3,3′-dimethylglutaric, fumaric and maleic, oxydiacetic and oxydipropanoic, thiodiacetic and thiodipropanoic, iminodiacetic, and 4,4′-diphenyldicarboxylic were subjected to the Fries rearrangement. The diesters of the acids containing a double bond, an oxygen linkage and an imino linkage did not

undergo rearrangement, while the diesters of the remaining acids gave the desired bis(o-hydroxyketones).

In order to further ascertain the scope and limitations of the double Fries rearrangement, diesters of biphenols containing the -S-, -O-, $-SO_2-$, $-CH_2CH_2-$ and $>C(CH_3)_2$ linkages have been prepared and subjected to the Fries rearrangement.

II. DISCUSSION

I. Preparation of Biphenols.

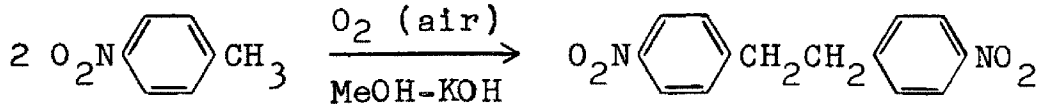
A. 1,2-Bis(4-hydroxyphenyl)ethane[14]

1. 1,2-Bis(4-nitrophenyl)ethane. Oxidative coupling of two moles of p-nitrotoluene in a saturated alcoholic-potassium hydroxide solution gave 1,2-bis(4-nitrophenyl)-ethane and some 1,2-bis(4-nitrophenyl)ethene, the relative amounts of each depending upon experimental conditions. Initial cooling of the reaction mixture to 5° for two hours followed by reaction at room temperature for an additional six hours, yielded a thick green-yellow mixture which when washed gave an orange solid consisting of 1,2-bis(4-nitrophenyl)ethane and 1,2-bis(4-nitrophenyl)ethene in a ratio of 4:1.[15] After separating the 1,2-bis(4-nitrophenyl)ethane from the mixture by extractions with hot benzene, the 1,2-bis(4-nitrophenyl)ethene was dissolved in chlorobenzene, leaving a small amount of a dark-orange insoluble material. This insoluble solid was reported[16] to be a polymerization product of 1,2-bis(4-nitrosophenyl)ethene. The actual compound is thought to be dinitroazodistilbene:

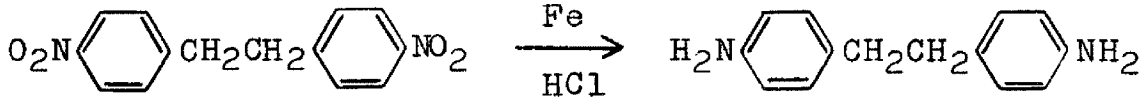
$$O_2N\text{-}C_6H_4\text{-}CH{=}CH\text{-}C_6H_4\text{-}N{=}N\text{-}C_6H_4\text{-}CH{=}CH\text{-}C_6H_4\text{-}NO_2$$

The reaction seemed to be somewhat temperature dependent. If the coupling was carried out at a lower temperature (10-15°) for the greater portion of the reaction time, the

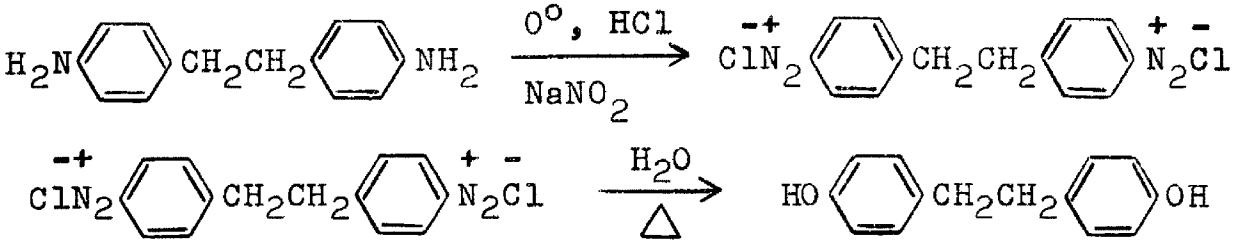
product consisted solely of 1,2-bis(4-nitrophenyl)ethane. Running the coupling reaction at a warmer temperature (30-40°) gave only the dark-orange insoluble material.



2. 1,2-Bis(4-aminophenyl)ethane. Treating 1,2-bis-(4-nitrophenyl)ethane with iron powder and concentrated hydrochloric acid gave 1,2-bis(4-aminophenyl)ethane as white plates in yields of 88 to 96%.

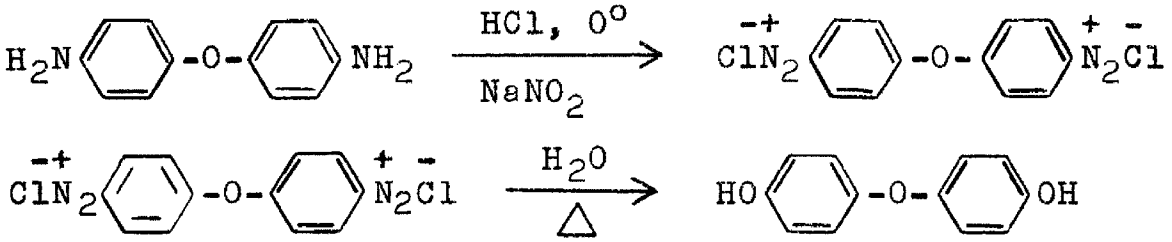


3. 1,2-Bis(4-hydroxyphenyl)ethane. Tetrazotization of 1,2-bis(4-aminophenyl)ethane followed by hydrolysis at elevated temperatures gave 1,2-bis(4-hydroxyphenyl)ethane in yields varying from 66 to 74%. A purple color in the starch-iodide test indicated that an excess of nitrous acid was present in the reaction solution. Boiling the solution for two hours or until the evolution of nitrogen ceased caused hydrolysis of the tetrazo salt to 1,2-bis(4-hydroxyphenyl)-ethane. A large excess (1 mole) of hydrochloric acid was used to insure that the final tetrazo solution would be acidic.



B. Bis(4-hydroxyphenyl)oxide

Bis(4-aminophenyl)oxide[a] was tetrazotized by sodium nitrite and hydrochloric acid and then hydrolyzed to bis(4-hydroxyphenyl)oxide by heating to boiling. Tetrazotization was accomplished in a similar manner to that described for 1,2-bis(4-hydroxyphenyl)ethane.



This tetrazo solution was stable to heat and resistant to hydrolysis. Only after prolonged refluxing (24 hrs.) was the tetrazo solution converted to an appreciable amount of the biphenol. A large amount of a black intractable tar was also formed during the extended period of refluxing.

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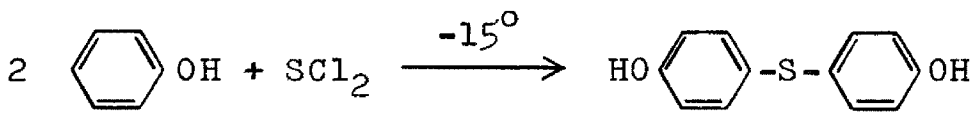
[a]A sample of bis(4-aminophenyl)oxide was obtained from the Dow Chemical Company, Midland, Michigan.

C. Bis(4-hydroxyphenyl)sulfide

1. Sulfur dichloride. Prepared according to the method of Brauer.[17] The sulfur dichloride obtained from the first distillation was of sufficient purity to be used in the preparation of bis(4-hydroxyphenyl)sulfide.

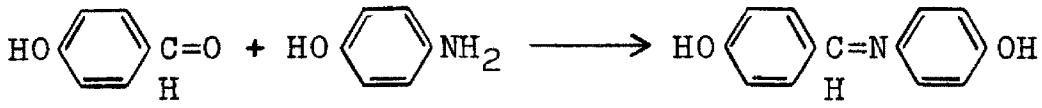
2. Bis(4-hydroxyphenyl)sulfide. Bis(4-hydroxyphenyl)-sulfide was prepared by the reaction of sulfur dichloride and phenol. Slow addition of a cold solution of sulfur dichloride and carbon disulfide to a cold solution of phenol and carbon tetrachloride produced a white precipitate of bis(4-hydroxyphenyl)sulfide. It was found[18] that if the reaction mixture was stirred vigorously after removal of the cooling bath, the yield of product was greatly improved. The product was obtained as a granular white powder in 80% yield.



D. 4-(4-Hydroxybenzylideneamino)phenol

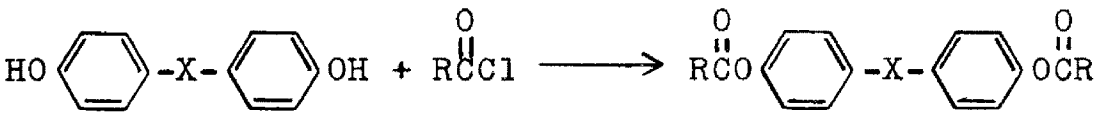
A mixture of equal molar amounts of p-hydroxybenzaldehyde and p-aminophenol was boiled for a few minutes in chloro-benzene to give 4-(4-hydroxybenzylideneamino)phenol. The dark-green solid was washed with benzene to remove any unreacted p-hydroxybenzaldehyde and recrystallized from

chlorobenzene to remove the unreacted p-aminophenol. The pure solid was light yellow in color.



II. Preparation of Diesters.

The diacetate and dibenzoate esters of the biphenols were all prepared by mixing a slight excess of two moles of the appropriate acid chloride with one mole of the biphenol.



where X represents -S-, -O-, $-CH_2CH_2-$, or $>C(CH_3)_2$;
and R represents $-CH_3$, or $-C_6H_5$.

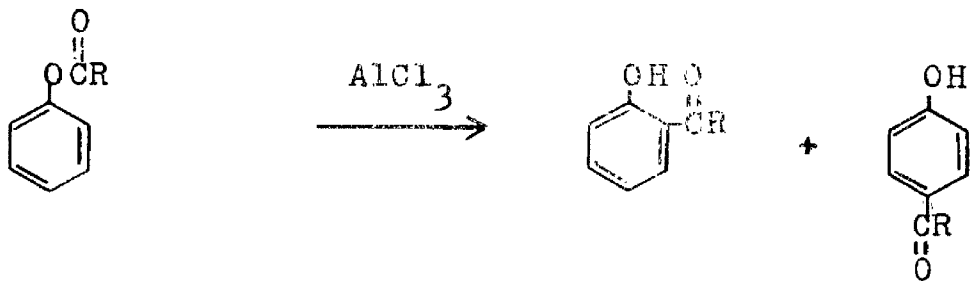
A very poor yield of 1,2-bis(4-benzoxyphenyl)ethane was obtained if benzene was the solvent, but if chlorobenzene was used as the solvent the yield was increased to 19%.

The preparation of the diacetate ester of 4-(4-hydroxybenzylideneamino)phenol was attempted using two different proceedures, neither of which was successful. Using the proceedure described above, a light, cream colored solid was obtained. This crystalline material had a melting point that corresponded to the reported melting point of p-hydroxyacetanilide and indicated that cleavage of the carbon-nitrogen

double bond had occurred. In the second proceedure, the biphenol and acetic anhydride were mixed in benzene and zinc chloride was added as a catalyst. The solid obtained from this reaction could not be identified and the infrared spectra did not correspond to those of the other diesters. All pertinent data are assembled in tables III and IV.

III. The Double Fries Rearrangement. Preparation of Bis(o-hydroxyketones).

The following equation represents a typical single Fries rearrangement.

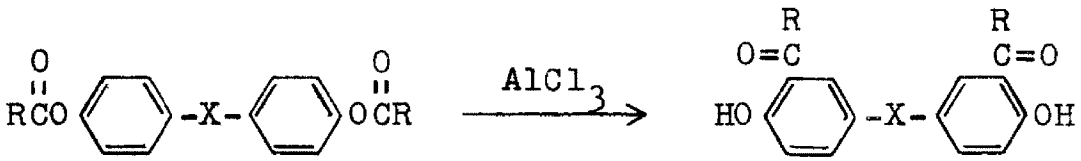


If a phenolic ester is treated with aluminum chloride, a conversion to either the ortho- or para-hydroxyketone, or both, occurs. The position, relative to the hydroxyl group, taken by the migrating acyl group depends upon the temperature at which the reaction is run, upon the nature of the acyl group, and upon the structure of the phenol. The amount of o-hydroxyketone formed can generally be increased by increasing the reaction temperature and by increasing the size of the acyl group. A methyl group ortho to the hydroxyl group

favors the formation of p-hydroxyketones while the same group in the meta-position favors formation of o-hydroxyketones. Esters with substituents in the para-position furnish only o-hydroxyketones.

This research problem deals with the double Fries rearrangement of the diesters of biphenols which are substituted in the para-position.

The following reaction illustrates the double Fries rearrangement of the diesters of para-substituted biphenols.



Since only o-hydroxyketones can be obtained in a reaction of this type, certain of the conditions which were necessary for the single Fries rearrangement no longer apply. The most important factors related to this study are the nature of the linkage between the two ester groups and the structure of the acyl group. A comparison of the rearrangement of the acetate and benzoate esters of thymol shows that thymyl acetate undergoes the conversion to thymyl methyl ketone in 60% yield in five hours. The benzoate ester, however, is converted in a 4% yield in an equal length of time. Thus it appears that the time required for the rearrangement of benzoate esters would be much greater than the time required for the rearrangement of acetate esters. To a limited extent this has been observed to be true. The diacetate and

dibenzoate esters of 4,4-biphenol have been reported[11] to undergo rearrangement in 19 and 30% yields, respectively. The reaction times were 24 hours for the diacetate ester and 3 days for the dibenzoate ester. Roffler and Thomas[12] obtained bis(o-hydroxyketones) from the diacetate and dibenzoate esters of bis(4-hydroxyphenyl)methane in 50% and 45% yields, respectively, reaction times of 12 hours for the diacetate and 24 hours for the dibenzoate ester. It must be noted, however, that these reaction times were not necessarily the minimum times required for obtaining the bis(o-hydroxyketones).

A scale has been made[19] to depict the decreasing rate of migration of the acyl group on the basis of increasing size of the acyl group:

$C_nH_{2n+1}CO$ (where n=1...5)$>C_6H_5CH_2CO>C_6H_5CH_2CH_2CO>$ $C_6H_5CH{=}CHCO>C_6H_5CO$.

This order holds true for esters where the acyl group migrates to the para-position as well as to the ortho-position, relative to the hydroxyl group.

Attempts to rearrange the di-p-tolyl esters of aliphatic dicarboxylic acids[13] which contained either a sulfur, an oxygen, an imino, an isopropyl linkage, or a linkage containing a carbon-carbon double bond were succesful only for the esters with the isopropyl and sulfur linkages.

The biphenol diesters containing the oxygen, sulfur and isopropyl linkages were rearranged only for the diacetate esters. It is not yet understood what effect these linkages have on the double Fries rearrangement.

The following diesters underwent rearrangement to give the desired bis(o-hydroxyketones): 1,2-bis(4-acetoxyphenyl)-ethane, 2,2-bis(4-acetoxyphenyl)propane, bis(4-acetoxyphenyl)-oxide, bis(4-acetoxyphenyl)sulfide and the dibenzoate ester, 1,2-bis(4-benzoxyphenyl)ethane. The diesters which did not rearrange to give the desired products were bis(4-acetoxy-phenyl)sulfone and all the remaining dibenzoate esters.

Several similarities between the rearranged products of biphenol diesters and the rearranged products of esters of dicarboxylic acids[13] containing the same linkage between the ester groups are noted. Consideration of the diesters containing the sulfur linkage reveals that the diacetate ester of bis(4-hydroxyphenyl)sulfide and the di-p-tolyl esters of thiodiacetic and thiodipropanoic acids underwent rearrangement in 23%, 55% and 44% yields, respectively. The dibenzoate ester of bis(4-hydroxyphenyl)sulfide, however, did not undergo rearrangement. In contrast to the rearrange-ment of esters with the sulfur linkage, the dicarboxylic acid esters[13] containing the oxygen linkage did not undergo rearrangement, while bis(4-acetoxyphenyl)oxide was rearranged in 20% yield.

The double Fries rearrangement involved, essentially, the mixing, with stirring, of a 1:2.1 mole ratio of diester to anhydrous aluminum chloride. The length of time allowed for reaction varied with the ester, but was generally 24 hours or until the evolution of hydrogen chloride ceased. A volume of 2N hydrochloric acid, approximately equal to the volume of solvent used, was added to the reaction mixture to decompose the aluminum chloride complex. It was found that if the organic solvent was removed by vacuum distillation, decomposition and colorization of the product was reduced. A 4:1 mole ratio of aluminum chloride to diester was also tried for the rearrangement of bis(4-benzoxyphenyl)oxide, bis(4-benzoxyphenyl)sulfide and bis(4-benzoxyphenyl)sulfone but as before no product could be isolated from the oils which formed. All rearranged products except 2,2-bis(3-acetyl-4-hydroxyphenyl)propane were obtained as solids when the solvent was removed. The 2,2-bis(3-acetyl-4-hydroxyphenyl) propane, however, was obtained as an oil which was very resistant to crystallization. The oil was finally mixed with a small amount of alcohol and allowed to cool in the refrigerator. After two months of cooling, a trace amount of white crystals were isolated.

The bis(o-hydroxyketones): 1,2-bis(3-acetyl-4-hydroxyphenyl)ethane and 2,2-bis(3-acetyl-4-hydroxyphenyl)propane were obtained as white crystals while the rearranged products of bis(4-acetoxyphenyl)oxide, bis(4-acetoxyphenyl)sulfide

and 1,2-bis(4-benzoxyphenyl)ethane were obtained as yellow crystals. To confirm the structure of bis(3-acetyl-4-hydroxyphenyl)sulfide an independent synthesis[20] was undertaken. A 2:1 mole ratio of o-hydroxyacetophenone and thionyl chloride was mixed with copper dust as the catalyst. The infrared spectra and melting point of the purified product were identical to the infrared spectra and melting point of the compound obtained by the double Fries rearrangement. A mixed melting point showed no depression.

III. INFRARED SPECTRA

The phenolic hydroxyl absorption band of the biphenols used in this investigation was observed at 2.80-3.02μ (3572-3311cm.$^{-1}$) instead of at 2.74-2.79μ (3644-3605cm.$^{-1}$) which is the reported absorption band for the hydroxyl group.[21] It has been shown[22] that the free phenolic hydroxyl absorption band for substituted phenols is shifted slightly due to the influence of the aromatic ring.

All the infrared spectra of the diacetate esters show a strong absorption band in the region of 5.70-5.75μ (1754-1732cm.$^{-1}$). This corresponds to the carbonyl absorption frequency of 5.71-5.76μ (1750-1735cm.$^{-1}$) reported[23] for normal saturated esters. For unsaturated esters such as the benzoates, the reported[24] absorption band occurs in the 5.80-5.81μ (1724-1719cm.$^{-1}$) region. The absorption band observed for the dibenzoate esters of the biphenols occurs at 5.80μ (1724cm.$^{-1}$).

The infrared spectra of the bis(o-hydroxyketones) show no absorption in the 2.77-2.79μ (3610-3584cm.$^{-1}$) region characteristic of the free phenolic hydroxyl group. Martin[25] observed that the infrared spectra of both salicylaldehyde and o-hydroxyacetophenone exhibited broad bands extending from 3.6μ (2778cm.$^{-1}$) to 2.8μ (3531cm.$^{-1}$) which were

attributed to the absorption of the hydroxyl group hydrogen bonded to the carbonyl group and, in part, to the carbon-hydrogen stretching frequency. All of the bis(o-hydroxyketones) derived from biphenols have a broad, weak band in the region of 3.1-3.6μ (3226-2778cm.$^{-1}$) which may be attributed to the hydroxyl group hydrogen bonded to the o-carbonyl and to the carbon-hydrogen stretching frequency.

For acetophenone[26] the carbonyl absorption frequency was found at 5.95μ (1670cm.$^{-1}$) while for o-hydroxyacetophenone it was shifted to 6.17μ (1621cm.$^{-1}$). Absorption also occurred around 6.30μ (1587cm.$^{-1}$) which may be attributed to the benzene ring. In each of the bis(o-hydroxyketones) there was no carbonyl absorption at 5.80-6.00μ (1724-1667cm.$^{-1}$) but there was strong absorption in the 6.07-6.21μ (1647-1576cm.$^{-1}$) region. Each of the absorption bands possessed two peaks except for 1,2-bis(3-acetyl-4-hydroxyphenyl)ethane and bis(3-acetyl-4-hydroxyphenyl)sulfide, each of which had one peak. These peaks could be indicative of the shifted carbonyl and of the benzene ring absorption. Gordy[26] noted that for o-hydroxyacetophenone there was no appreciable separation between the carbonyl absorption and benzene ring absorption in this region. In addition to the single peak mentioned for the compounds above, there was another weak absorption peak at 6.3μ (1578cm.$^{-1}$). This could be attributed to the benzene ring absorption in these compounds.

TABLE I

Infrared Absorption Spectra of Bis(o-hydroxyketones)

Bis(o-hydroxyketones)	3.20-3.50μ	3125-2857cm.$^{-1}$	6.07-6.50μ	1647-1538cm.$^{-1}$
2,2-Bis(3-acetyl-4-hydroxyphenyl)propane	3.27	2967	6.11 6.20 6.28	1636 1612 1592
1,2-Bis(3-acetyl-4-hydroxyphenyl)ethane	3.43	2915	6.09 6.31	1642 1584
1,2-Bis(3-benzoyl-4-hydroxyphenyl)ethane	3.30 3.41 3.50	3030 2932 2857	6.13 6.22 6.35	1631 1607 1575
Bis(3-acetyl-4-hydroxyphenyl)sulfide	3.43	2915	6.10 6.30 6.41	1639 1587 1560
Bis(3-acetyl-4-hydroxyphenyl)oxide	3.27 3.40	3058 2941	6.08 6.16 6.31	1644 1623 1585

IV. EXPERIMENTAL[a]

I. Biphenols

A. Intermediates

1. 1,2-Bis(4-nitrophenyl)ethane.

A mixture of p-nitrotoluene (25 g., 0.18 mole) and 500 ml of 33% methanolic-potassium hydroxide was placed in a two liter Erlenmeyer flask. The flask was immersed in an ice bath and a rapid stream of air was bubbled through the mixture. The mixture was kept at 5-10° for two hours during which time the light yellow color changed to a deep violet color. The ice bath was removed and air was bubbled through the mixture for an additional six hours. The greenish-yellow mixture was filtered by suction and the filter cake was washed with 500 ml of boiling water, 75 ml of cold alcohol, and air dried. Yield: yellow powder, 14.5 g. (58%), m.p. 177-179°; reported m.p. 179-180°.[14]

2. 1,2-Bis(4-aminophenyl)ethane.

A solution of 2.1 ml concentrated hydrochloric acid in 19.6 m. of 1:1 alcohol-water was added dropwise to a mixture of powdered iron (35.2 g., 0.63 mole) and 1,2-bis(4-nitrophenyl)ethane (22.3 g., 0.08 mole) in 196 ml of 1:1

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[a]All melting points are uncorrected. Analysis by Galbraith Microanalytical Laboratories, Knoxville, Tenn.

alcohol-water. After refluxing and stirring for seven hours, the black mixture was made basic to litmus with 10% sodium hydroxide. Sufficient ethanol (320 ml) was added to dissolve all the diamine and the hot mixture was filtered. The filtrate was cooled and the crude flakes were collected and dried. Yield: light brown flakes, 6.72 g. (69%), m.p. 135-140°. A sample of the crude product was recrystallized twice from 1:1 ethanol-water to give white plates, m.p. 138-139°; reported m.p. 135-137°.[14]

3. Sulfur dichloride.

Chlorine, dried by passing through phosphorus pentoxide, was passed into powdered sulfur (192.6 g., 6.0 mole) contained in a two-necked round bottomed flask fitted with a reflux condenser and a gas inlet tube. The dry chlorine was passed into the dark-red solution until the absorption of gas slowed. Approximately 0.1 gram of powdered iron was added to act as a catalyst and more chlorine was bubbled through the liquid. After several hours the chlorine inlet tube was removed and a Vigreaux tube was attached. The dark-red sulfur dichloride was distilled and a fraction boiling between 59° and 62° was collected. Three drops of phosphorus trichloride were added to the sulfur dichloride to prevent decomposition and the product was stored in a sealed container in the refrigerator. Yield: dark-red liquid, 198.4 g. (32%).

B. 1,2-Bis(4-hydroxyphenyl)ethane.

Concentrated hydrochloric acid (75 ml) was added dropwise, with cooling and stirring, to 1,2-bis(4-aminophenyl)-ethane (7.35 g., 0.035 mole) in 500 ml of water. The solution was cooled to 5° in an ice bath and 90% of a sodium nitrite solution (5 g. in 38 ml of water) was added in one portion. The remainder of the sodium nitrite solution was added dropwise until a lasting purple starch-iodide test was obtained. The dark-red solution was stirred and heated at reflux until the evolution of nitrogen ceased. The brown precipitate was collected and recrystallized from 3:1 water-ethanol. Yield: light brown flakes, 5.46 g. (73%), m.p. 179-189°. A sample of the crude product was recrystallized four times from 3:1 water-ethanol to give white flakes, m.p. 196-198°; reported m.p. 189°,[27] 197-198°,[28] 195-196°,[14] 198°.[29]

C. Bis(4-hydroxyphenyl)oxide

Bis(4-aminophenyl)oxide (14.7 g., 0.074 mole) was dissolved in one liter of water by the dropwise addition of 150 ml of concentrated hydrochloric acid. The solution was filtered and 90% of a sodium nitrite solution (10 g. in 76 ml of water) was added in one portion to the ice cold filtrate. The remainder of the sodium nitrite solution was added dropwise until a lasting purple starch-iodide test was obtained. The red solution was boiled until the evolution of nitrogen slowed and the color changed to yellow. The

yellow solution was then poured into a flask and refluxed until the evolution of nitrogen ceased and the hydrolysis was complete. The hot mixture was filtered and cooled to give bis(4-hydroxyphenyl)oxide. Yield: white flakes, 6.5 g. (44%), m.p. 154-158°. A sample of the crude product was recrystallized five times from water to give white flakes, m.p. 163-164.5°; reported m.p. 160-161°,[30] 195-196°,[31] 165-167°.[32]

D. Bis(4-hydroxyphenyl)sulfide.

Phenol (94.1 g., 1.0 mole) was dissolved in one liter of carbon tetrachloride contained in a two liter, three-necked flask. The flask was fitted with a stirrer, reflux condenser and a dropping funnel which served for addition of the sulfur dichloride-carbon disulfide solution. Sulfur dichloride (51.5 g., 0.50 mole) was dissolved in 80 ml of carbon disulfide and cooled to -10°. The reaction flask was immersed in a salt-ice bath and the sulfur dichloride was added in small portions with stirring. The addition of sulfur dichloride took one hour during which time a large amount of hydrogen chloride was evolved. After addition was complete the salt-ice bath was removed and the reaction mixture was stirred at room temperature for one hour. The white precipitate was collected and air dried. Yield: white powder, 70.4 g. (78%), m.p. 149-151°. A small portion of the

crude product was recrystallized twice from benzene to give white crystals, m.p. 150-151°; reported m.p. 150°,[33] 150-151.5°,[34] 151°.[18]

E. 4-(4-Hydroxybenzylideneamino)phenol.

Into an Erlenmeyer flask containing 100 ml of chlorobenzene was placed p-aminophenol (22.3 g., 0.20 mole). To this mixture was slowly added with stirring p-hydroxybenzaldehyde (25 g., 0.20 mole). The mixture was heated to boiling for five minutes to azeotrope the water formed during the reaction. The hot mixture was filtered and the dark-green solid was air dried. The filtrate was allowed to cool and the solid which precipitated was collected. Yield: dark-green powder, 30.5 g. (70%), m.p. 194-199°. A portion of the crude product was recrystallized four times from chlorobenzene to give light yellow crystals, m.p. 207.5-208°; reported m.p. 202°,[35] 208°.[36]

TABLE II

Biphenols

Biphenol	M.P., °C.	Recrystallization Solvent	Yield, %
1,2-Bis(4-hydroxyphenyl)ethane	196-198[a]	3:1 water-ethanol	73
Bis(4-hydroxyphenyl)oxide	163-164.5[b]	water	44
Bis(4-hydroxyphenyl)sulfide	150-151[c]	benzene	78
4-(4-hydroxybenzylideneamino)phenol	207.5-208[d]	chlorobenzene	70

[a]Reported m.p.: 189°,[27] 197-198°,[28] 195-196°,[14] 198°.[29]

[b]Reported m.p.: 160-161°,[30] 195-196°,[31] 165-167°.[32]

[c]Reported m.p.: 150°,[33] 150-151°,[34] 151°.[18]

[d]Reported m.p.: 202°,[35] 208°.[36]

II. Biphenol Diesters

All of the diacetate and dibenzoate esters were prepared in the same general manner using the same molar ratios as described for 2,2-bis(4-acetoxyphenyl)propane. Pertinent data are assembled in tables III and IV.

A. 2,2-Bis(4-acetoxyphenyl)propane.

A solution of acetyl chloride (5.9 g., 0.08 mole) in 20 ml of dry benzene was added in one portion to a solution of 2,2-bis(4-hydroxyphenyl)propane (6.9 g., 0.03 mole) in 20 ml of dry benzene contained in a 200 ml three-necked flask. The flask was fitted with a thermometer and reflux condenser connected to a Gilman trap. The Gilman trap was filled with sulfuric acid and the exit led to a water trough. The reaction mixture was heated to reflux by means of a heating mantle. The solution was refluxed overnight and then poured, while hot, into a suction flask and the benzene removed under vacuum. The solid which remained was dissolved in 40 ml of 1:1 ethanol-water and some Norit was added. The mixture was refluxed for several minutes, filtered and the filtrate cooled. The product was collected and air dried. Yield: light brown crystals, 7.4 g. (79%), m.p. 78-80°. A small portion of the crude product was recrystallized twice from 1:1 ethanol-water to give white crystals, m.p. 80-81°; reported m.p. 79-81.5°,[40] 78°.[41]

TABLE III

Diacetate esters

Diester	M.P., °C.	Recrystallization Solvent	Yield, %	Analysis Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
Bis(4-acetoxyphenyl)-sulfone	163-4[a]	ethanol	47	57.50	57.30	4.19	3.99
2,2-Bis(4-acetoxyphenyl)-propane	80-1[b]	1:1 ethanol-water	83				
1,2-Bis(4-acetoxyphenyl)-ethane	114-6[c]	ethanol	71				
Bis(4-acetoxyphenyl)-oxide	111-3	ethanol	75	67.15	66.93	4.89	4.93
Bis(4-acetoxyphenyl)-sulfide	92-3[d]	ethanol	81				

[a]Reported m.p.: 163-5°,[37] 170-1.5°,[38] 165°.[39]

[b]Reported m.p.: 79.5-81.5°,[40] 78°.[41]

[c]Reported m.p.: 116-7°,[42] 115-6°.[20]

[d]Reported m.p.: 92-4°.[43]

TABLE IV

Dibenzoate esters

Diester	M.P., °C.	Recrystallization Solvent	Yield, %	Analysis Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
2,2-Bis(4-benzoxyphenyl)-propane	157.5-9[a]	ethanol	30	79.50	79.59	5.84	5.62
Bis(4-benzoxyphenyl)-sulfone	244-5[b]	toluene	57				
1,2-Bis(4-benzoxyphenyl)-ethane	190-1[c]	toluene	69	79.63	79.42	5.21	5.08
Bis(4-benzoxyphenyl)-oxide	144-5	ethanol	39				
Bis(4-benzoxyphenyl)-sulfide	147-8	1:1 ethanol-dioxane	54	73.25	73.06	4.22	4.10

[a]Reported m.p.: 153.5°.[44]

[b]Reported m.p.: 246°,[45] 243°,[46] 248.5°,[47] 245-7°.[48]

[c]Reaction solvent-chlorobenzene.

III. Bis(o-hydroxyketones).

All rearrangements were made with the same molar proportions and in the same general manner as described for 1,2-bis-(4-acetoxyphenyl)ethane. All pertinent data are assembled in table V.

A. 1,2-Bis(3-acetyl-4-hydroxyphenyl)ethane.

Anhydrous aluminum chloride (3.4 g., 0.03 mole) was added slowly, with vigorous stirring and cooling, to a solution of 1,2-bis(4-acetoxyphenyl)ethane (3.0 g., 0.01 mole) and 30 ml of dry chlorobenzene in a 200 ml three-necked flask. After complete addition of the aluminum chloride, the salt-ice bath was removed and the green mixture was allowed to warm to room temperature with continued stirring. The stirrer was replaced by a reflux condenser connected to a Gilman trap and the mixture was refluxed overnight. During this time hydrogen chloride was evolved and a yellow precipitate formed. The mixture was cooled and stirred in an ice bath and 40 ml of 2N hydrochloric acid was added dropwise. The chlorobenzene was removed by steam distillation and the dark residue recrystallized from 1:1 ethanol-water. Yield: white crystals, 0.64 g. (21%). A small portion of the crude product was recrystallized three times from 1:1 ethanol-water to give white crystals, m.p. 190-191.5°.

B. Bis(3-acetyl-4-hydroxyphenyl)sulfide.

Thionyl chloride (50 g., 0.42 mole) and o-hydroxyacetophenone (26.8 g., 0.19 mole) were mixed in a 200 ml

three-necked flask which was fitted with a reflux condenser and thermometer. Copper dust (20 g., 0.31 mole) was added and the mixture heated to start the reaction. The mixture was then allowed to react at room temperature for 70 hours. The flask was heated for one-half hour in a water bath and the material in the flask dissolved in hot ethanol. The product was obtained as yellow-green crystals, m.p. 195-198°. A small portion of the crude product was recrystallized twice from ethanol to give light yellow crystals, m.p. 198.5-200°; reported m.p. 196-197°.[20]

TABLE V

Fries Rearrangement of Diesters

Bis(o-hydroxyketones)	Recrystallization Solvent	M.P., °C.	Yield, %	Analysis			
				Carbon, %		Hydrogen, %	
				Calcd.	Found	Calcd.	Found
2,2-Bis(3-acetyl-4-hydroxyphenyl)propane	ethanol	140-1	trace	73.09	73.27	6.41	6.48
1,2-Bis(3-acetyl-4-hydroxyphenyl)ethane	ethanol	190-1	21	72.47	72.23	6.08	6.04
Bis(3-acetyl-4-hydroxyphenyl)oxide	ethanol[a]	179.5-81	20	67.13	66.96	4.93	4.99
Bis(3-acetyl-4-hydroxyphenyl)sulfide	1:1 ethanol-dioxane	198-200[b]	23	63.58	63.78	4.63	4.64
1,2-Bis(3-benzoyl-4-hydroxyphenyl)ethane	toluene	206-7	19	79.63	79.67	5.21	5.23

[a]Reaction solvent-1,2-dichloroethane.

[b]Reported m.p.: 196-7°.[20]

V. SUMMARY

The following biphenols have been prepared: 1,2-bis-(4-hydroxyphenyl)ethane, bis(4-hydroxyphenyl)oxide and bis-(4-hydroxyphenyl)sulfide. These biphenols along with bis-(4-hydroxyphenyl)sulfone and 2,2-bis(4-hydroxyphenyl)propane were esterified and subjected to the double Fries rearrangement. The biphenol, 4-(4-hydroxybenzylideneamino)phenol was prepared, but attempts at esterification were unsuccessful. The only products obtained were decomposition products.

The diacetate esters: 1,2-bis(4-acetoxyphenyl)ethane, bis(4-acetoxyphenyl)oxide, bis(4-acetoxyphenyl)sulfide and 2,2-bis(4-acetoxyphenyl)propane were rearranged to give 1,2-bis(3-acetyl-4-hydroxyphenyl)ethane, bis(3-acetyl-4-hydroxyphenyl)oxide, bis(3-acetyl-4-hydroxyphenyl)sulfide and 2,2-bis(3-acetyl-4-hydroxyphenyl)propane, respectively.

Only one dibenzoate ester underwent rearrangement. The rearrangement of 1,2-bis(4-benzoxyphenyl)ethane gave 1,2-bis-(3-benzoyl-4-hydroxyphenyl)ethane.

The infrared spectra of the bis(o-hydroxyketones) show no absorption band for the free phenolic hydroxyl group, but do show a broad absorption band which may be attributed to the hydroxyl group hydrogen bonded to the o-carbonyl and to the carbon-hydrogen stretching frequency. The carbonyl group absorption was shifted to higher wave lengths than that observed for the carbonyl absorption of the diesters.

A separate synthesis of bis(3-acetyl-4-hydroxyphenyl)-sulfide was undertaken to confirm the structure of the product obtained from the double Fries rearrangement of bis(4-acetoxyphenyl)sulfide.

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